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ATTENUATION OF GAMMA RAYS at Oblique Incidence

THE NATIONAL BUREAU OF STANDARDS has recently completed an investigation of the attenuation of gamma radiation incident obliquely on barriers of lead, concrete, and concrete-equivalent material. This study, sponsored by the Atomic Energy Commission, was conducted by F. S. Kirn, R. J. Kennedy, and H. O. Wyckoff of the Bureau staff. The results indicate that considerable error may be involved in some estimates of protective barrier thickness necessary to produce a specified attenuation. Estimates based on attenuation data for normally incident radiation were found to be several half-value layers low for obliquely incident radiation of the same energy.

The high cost and heavy weight of barriers required for protection against high-energy X- or gamma radiations warrant a detailed study of the factors involved in obtaining an economical solution to the protection problem. The Bureau has for several years conducted research on radiation protection design. Several NBS radiation protection Handbooks, containing recommendations of the National Committee on Radiation Protection, have been compiled.¹ However, until now no detailed experimental or theoretical evaluation has been made of the attenuation of radiation obliquely incident on radiation barriers.

When radiation is directed at a barrier, the attenuation is usually assumed to be related to the barrier thick-

ness traversed by the unscattered portion of the beam, regardless of the incident angle of the radiation. This assumption, however, may lead to a significant underestimate of the barrier thickness required to produce a specified attenuation.

In most protection problems scattered radiation makes an important contribution to the transmission of the barrier. When radiation is normally incident, the scattered radiation which emerges from the barrier must always travel a greater distance within the barrier than that traveled by the unscattered radiation. In oblique incidence, however, some of the scattered radiation travels a much shorter distance within the barrier than the unscattered radiation. As a result, in oblique incidence the scattered radiation may become the predominant component of the total radiation transmitted by the barrier.

The present study was initiated primarily to determine the dependence of this "obliquity effect" on variations in (1) incident photon energy, (2) angle of incidence, and (3) barrier material for an initially parallel beam of radiation. Gamma radiation from cobalt-60, cesium-137, and gold-198 was used at incidence angles of 0°, 30°, 50°, 60°, and 70°.

The source of gamma radiation was placed at the end of a lead collimator whose opening was approximately 16 in. long, 3 in. high, and 0.25 to 0.5 in. wide. The

Schematic drawing of experimental arrangement used in NBS study of oblique-incidence gamma-ray attenuation. Right: Source holder and collimator. Left: Absorber and ionization chamber.

distance from the gamma source to the radiation detector was seven feet. This distance and the collimator dimensions defined a beam 40 in. high and about 2½ in. wide at the detector. With this arrangement the dose rate in a vertical plane containing the detector was constant to within 3 percent in the vertical direction and to within 2 percent over the width of the beam. The entire collimator and source were placed on a rolling table which could be rotated at a fixed radius about an axis through the center of the detector. Absorber material was placed between the gamma source and the detector.

The detector was a specially constructed ionization chamber with a sensitive length of about 70 inches. It was made from a 1/8 in. wall tube of near-air-equivalent material, with an outside diameter of 1½ in. The inner surface was coated with a conducting layer of colloidal graphite. The center electrode was an aluminum wire, also coated with graphite, supported at both ends with electrostatically shielded amber insulators. An ion collecting potential of 180 volts was sufficient for saturation. Ionization chambers of this general type have a calibration that is independent of photon energy within 10 percent for energies down to 150 kev.

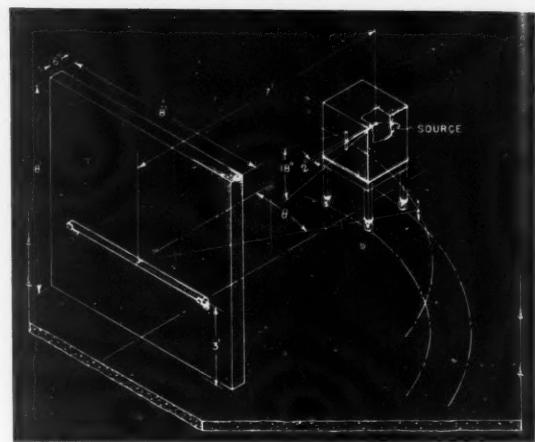
Ionization current was measured by a vibrating reed electrometer used as a null indicator and a portable potentiometer used to supply the bucking voltage. Calibrated resistors and capacitors were employed to give an adequate range of sensitivity.

Detector length required to obtain essentially all of the scattered radiation was determined by an auxiliary experiment. The readings of a small ionization chamber were obtained as a function of its position along

TABLE 1. Dose rate (observed)/dose rate (estimated)*

Percent transmission estimated	50°		60°		70°	
	Concrete	Lead	Concrete	Lead	Concrete	Lead
Gold-198 (0.411 mev)						
10	1.1	—	1.2	—	1.2	1.0
1.0	2.0	—	2.7	—	4.0	1.0
0.1	3.7	—	7.0	—	15	1.5
Cesium-137 (0.661 mev)						
10	1.2	1.0	1.2	1.0	1.3	1.1
1.0	1.7	1.1	2.5	1.3	3.7	1.6
0.1	2.3	(1.2)	5.2	(1.7)	10.1	(2.8)
Cobalt-60 (1.33 and 1.17 mev)						
10	1.0	1.0	1.0	1.0	1.2	1.1
1.0	1.4	1.1	1.9	1.3	2.5	1.6
0.1	(2.0)	(1.3)	(3.5)	(1.9)	(5.6)	(2.8)

* This is the ratio of the dose rate as measured experimentally for oblique angles to that which is determined from normal incidence attenuation data for thickness of barrier equal to the slant thickness in the oblique barrier. Values in parentheses are obtained by linear extrapolation of curves.



the barrier. The readings indicated that nearly all the transmitted radiation is collected within a distance of 50 inches.

Data were taken for lead, concrete, and polyethylene absorbers. Composite barriers of lead and concrete or of lead and polyethylene were studied to determine the effects of combining these materials. In one case barriers of aluminum and steel were investigated.

Observed dose rates for oblique incidence were compared with the rates expected on the basis of normal incidence data for a barrier thickness equal to the oblique path length or "slant thickness." These comparisons indicate the error in dose rate that would be introduced by applying the curves for normal incidence

TABLE 2. Comparison of barrier thickness for a desired attenuation determined from estimated and experimental data*

Percent transmission	50°				60°				70°			
	Concrete (in.)		Lead (cm)		Concrete (in.)		Lead (cm)		Concrete (in.)		Lead (cm)	
	Est.	Exp.	Est.	Exp.	Est.	Exp.	Est.	Exp.	Est.	Exp.	Est.	Exp.
Gold-198												
10	4.4	4.8	—	—	3.4	3.9	—	—	2.3	2.7	0.34	0.6
1.0	7.8	9.1	—	—	6.1	7.9	—	—	4.1	6.6	0.72	1.2
0.1	11.1	13.6	—	—	8.7	12.2	—	—	5.9	10.8	1.1	1.2
Cesium-137												
10	4.7	5.0	1.5	1.5	3.9	4.2	1.1	1.1	2.7	3.1	0.8	0.8
1.0	9.2	10.2	2.8	2.8	7.1	9.0	2.1	2.3	4.9	7.4	1.5	1.6
0.1	13.3	15.0	4.1	(4.1)	10.3	13.8	3.2	(3.4)	7.1	11.6	2.2	(2.5)
Cobalt-60												
10	6.7	6.6	2.7	2.7	5.2	5.3	2.1	2.1	3.6	3.9	1.5	1.5
1.0	12.0	12.9	5.3	5.4	9.1	10.9	4.1	4.4	6.4	8.1	2.8	3.2
0.1	17.3	(19.2)	7.8	(8.1)	13.5	(16.4)	6.1	(6.7)	9.2	(12.4)	4.2	(5.0)

* The estimated data were obtained from the experimentally determined attenuation with normally incident radiation and for a barrier thickness equal to the slant thickness in the oblique barrier. The experimental data were obtained for radiation incident obliquely on the barrier. Values in parentheses were obtained by linear extrapolation of curves.

to the oblique ray path. Table 1 illustrates the magnitude of the errors for the two most popular barrier materials, concrete and lead. Table 2 indicates the barrier thicknesses required for desired attenuations, both according to actual observation and according to the approximate method outlined in NBS Handbook 50 (see footnote 1), for several energies of incident gamma rays.

In the energy range studied, it appears from these comparisons that the expected error is greatest for the lowest energy used here (0.411 Mev) with low atomic number barriers and decreases with energy increase. For high atomic number materials the error is smaller, and the error-energy relationship is reversed. Spot checks indicated that the obliquity effect is somewhat smaller with conical beams of radiation.

From the results of this continuing study, it is obvi-

ous that an additional factor must be considered in any plan for construction of radiation protection barriers. Where the primary beam is directed obliquely at a barrier, the expected angles of beam incidence must be given proper evaluation in the construction plans. The present method, in which the dose rate expected beyond the barrier is computed on the basis of the slant distance alone, is insufficient for accurate results.

For further technical details, see The attenuation of gamma rays at oblique incidence, by F. S. Kirn, R. J. Kennedy, and H. O. Wykoff, *Radiology* **63**, No. 194 (1954).

¹ NBS Handbook 41, Medical X-ray protection (20 cents); NBS Handbook 50, X-ray protection design (15 cents); NBS Handbook 55, Protection against betatron-synchrotron radiations up to 100 million electron volts (25 cents). These Handbooks are available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at the prices indicated.

Subharmonic Crystal Oscillator

A SUBHARMONIC CRYSTAL OSCILLATOR circuit recently constructed at NBS combines simplicity with versatility and requires only a single triode tube in a blocking oscillator circuit, coupled to a quartz crystal. Each output pulse of the oscillator "shock excites" the crystal, and the voltage generated by the crystal as it continues to vibrate or "ring" synchronizes the oscillator at a submultiple of the crystal frequency. With some crystals the circuit has been operated successfully at division ratios as high as 10,000 to 1, producing harmonic-rich output at 100 cycles per second controlled by a 1,000 kilocycles-per-second crystal. The present circuit was a chance discovery of M. C. Thompson, Jr., of the NBS Sound Section, who, while working on a project sponsored by the Office of Naval Research, noticed that some equipment was oscillating in an unexpected fashion and proceeded to analyze and take advantage of the phenomenon. Although a search shows that a patent for a similar circuit was granted to W. A. Marrison in 1933, electronic engineers have apparently been almost entirely unaware of this signal-generating technique.

An ordinary blocking oscillator is a simple arrangement in which the plate circuit of a vacuum tube is coupled by means of a transformer to a resistor-capacitor combination in the grid circuit. When plate voltage is first applied the grid is at zero potential with respect to cathode, and plate current starts to flow through the primary (plate) winding of the transformer. This current quickly produces a large voltage pulse in the secondary that charges the capacitor in the grid circuit, driving the grid voltage far beyond the plate-current cutoff value. With the plate current thus cut off almost as soon as it has started, the grid capacitor discharges through the grid resistor until the grid voltage has



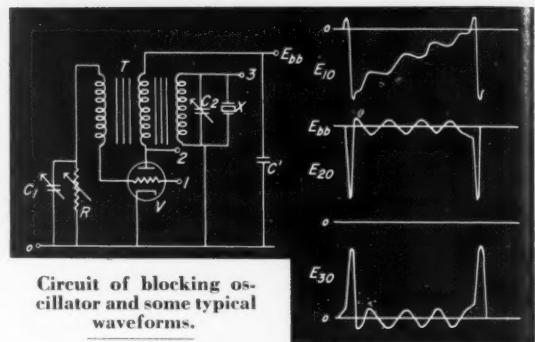
A communications receiver is used to check the output of a simple crystal-controlled blocking oscillator (small chassis) at NBS. The fundamental frequency of the oscillator, always a submultiple of the crystal frequency, is determined by the setting of a screw-driver-adjusted capacitor. At the rear is a power supply that provides heater and plate voltage for the triode oscillator. With a fundamental frequency of 1 kc controlled by a 1,000 kc crystal, useful harmonics were observed at frequencies up to 20 Mc and higher. Inset: Close-up of oscillator.

recovered sufficiently to again permit a plate current pulse to flow. The circuit keeps oscillating in this fashion, at a frequency determined largely by the time constant (product of resistance and capacitance) of the grid circuit. Blocking oscillators can be readily synchronized at submultiples of stable signals inserted in their grid circuits; as the grid recovers after being blocked, the tube will fire at or near a positive peak of the synchronizing voltage.

In the crystal-controlled blocking oscillator being used at NBS, the necessary synchronizing signal is obtained simply by coupling a quartz crystal to an ordi-

nary blocking oscillator, by means of a third transformer winding. Alternatively, the crystal can be connected across either the grid or plate winding of the transformer, or connected directly between grid and plate. Coupling by means of a third transformer winding seems preferable, however, since it avoids d-c voltage on the crystal and permits grounding the rotor of a trimmer condenser placed across the crystal.

Division ratios as high as 10,000 to 1 have been obtained only with a few crystals. Such extreme ratios would probably seldom be of practical value; a small change in circuit constants might cause the fundamental frequency to change from 1/10,000 to 1/10,001 of the crystal frequency, for instance, and such a small change in frequency could easily go undetected with ordinary equipment. Division ratios of several hundred are readily obtained, however, and can be maintained with high stability if supply voltages are held reasonably constant. Crystal-controlled signals can thus easily be generated at frequencies much lower than those of generally available crystals. The wide range of possible division ratios means that a desired fundamental frequency can be obtained from any of a large number of crystal frequencies. Conversely, a



Circuit of blocking oscillator and some typical waveforms.

single crystal can be used to give crystal-controlled output at any of a large number of fundamental frequencies. The upper limit of blocking-oscillator fundamental frequency is determined by the characteristics of the pulse transformer; this limit appears to be above 200 kilocycles with a typical transformer.

For further technical details, see Subharmonic crystal oscillators, by Moody O. Thompson, Jr., Carroll E. Tschigg, and Martin Greenspan, *Rev. Sci. Instr.* 25, 8 (1954).

Comparisons Made in Pairs

THE BUREAU is actively applying the methods of modern statistical inference to experiments in the physical sciences and engineering. Results at NBS have shown that statistical principles and techniques are even more useful in these areas than they are in agricultural and biological work, where many of them were first developed. Much of the work deals with the design of statistically planned experiments for greater precision and accuracy. Recent studies in this field by workers in the Bureau's statistical engineering laboratory provide methods of arranging paired observations in such a way as to obtain a maximum amount of information from a minimum amount of measurement and computation.

Paired observations are important in many scientific and engineering investigations—particularly those performed under conditions not easily reproduced. Tests or measurements of this kind are often made in a group under a single set of conditions in order to avoid errors arising from environmental changes. While such a group may be of any convenient size, depending on the experimental problem, in practice it is often limited to two paired observations. For example, materials for shoe soles might be compared under actual service conditions by putting two different kinds of soles on a pair and then measuring the resulting amount of wear. Obviously the results with those worn by different people would reflect the walking habits of the wearers, and thus whole pairs would not be strictly comparable. However, the pair worn by a single individual would provide two soles which would be subject to very much the same amount of wear because they were used under the same conditions.

Paired observations may also be used in the testing of tires. Tires are ordinarily tested in groups of four, and daily rotation is used to equalize wheel position and differences between the surface at the center and edge of the road. However, the comparison of tire treads is greatly improved when tires are made up so that half of the circumference of each tire has a tread made with one formula and the other half has a tread made with a different formula. Practically identical conditions are then obtained in road tests of each set of paired treads. A similar pairing is used in testing paints. Here variations in the wood that is painted influence performance. For this reason, comparisons are often made by painting one end of a short board with one paint and the other end with another paint.

Difficulties arise in paired observations when more than two items need to be compared. For example, it might be desirable to compare 10 different kinds of sole leather in paired service tests. The usual method is to place a common standard material in each of 10 pairs. The standard serves as a go-between for the various pairs so that different materials (*A*, *B*, *C*, etc.) may be reasonably well compared even though they are tested under slightly different conditions. The comparison is made by taking the difference between such quantities as (*A* - *S*) and (*B* - *S*), where *S* is the corresponding result for the standard.

However, six materials require 12 measurements, so half the measurement work is expended on the standard. Also, the result (*A* - *B*) involves the errors of measurements in both (*A* - *S*) and (*B* - *S*); whereas if *A* and *B* had been compared directly, only the error in measuring one difference would be involved. A

more important disadvantage of this limited experiment, with six pairs for six materials under test, is the fact that there is no way of using the results to estimate the size of the errors in the comparisons. These errors might be assumed to be of the same magnitude as those between different values obtained for the standard. However, the six results for the standard may differ considerably among themselves because different conditions prevail for different pairs. The error appropriate for the comparisons would then be much smaller than the differences among the six values for S would suggest.

An alternative procedure, which gives the best relative values of the six materials and permits estimation of error, consists in forming all possible 15 pairs among the 10 materials. This procedure has long been used by the Bureau for the intercomparison of standard meter bars. The bars are compared in pairs because the constant temperature chamber accommodates only two bars. Obviously it would be very difficult to hold the chamber at exactly the same temperature for all of the measurements. However, there is no need to attempt this if the bars are placed in the chamber in all possible pairings. The 15 differences that are obtained can be written in 15 equations of the form $A - B = d$, involving the six unknowns A through F . A least squares solution for the six unknowns gives the best relative values for the bars, one of which may be the standard.

The mathematics for the least squares solution is particularly simple when all possible 15 pairs have been measured, but an immediate objection is the large number of measurements needed. To compare 15 pairs of standard meter bars in this way requires 15 days. However, a considerable reduction in the number of measurements needed is made possible by the Bureau's recent studies of paired observations. Rules were devised for picking subsets of the total array of pairs that also lead to simple least square solutions. Instead of all 15 pairs, subsets of 9 or 12 may be used. One such subset is made up of the following selection of nine pairs:

AB	EB	FB
AC	EC	FC
AD	ED	FD

Here A is paired with B , C , and D ; and these three letters are in turn paired with the remaining number two letters, E and F .

Any letter is directly paired with three of the others and, through these three, indirectly paired with the remaining two letters. The nine pairs involve three measurements on each object. The usual procedure,

which calls for six pairs with a common standard, yields only one measurement on each object.

The pairs under the traditional scheme are

$$\begin{array}{ccccccc} S & S & S & S & S & S \\ A & B & C & D & E & F \end{array}$$

and comparisons between any of the letters such as A and B require that the difference between S and A be added to the difference between B and S . The nine pairs chosen in the new scheme give a *direct* and hence more precise comparison for A and B and also for the eight other pairs actually employed. There are six pairs of letters (AE , AF , BC , BD , CD , EF) not actually listed as pairs. For each of these, however, three indirect comparisons are available.

For example:

$$\begin{aligned} (A-B)+(B-E) &\rightarrow A-E \\ (A-C)+(C-E) &\rightarrow A-E \\ (A-D)+(D-E) &\rightarrow A-E \end{aligned}$$

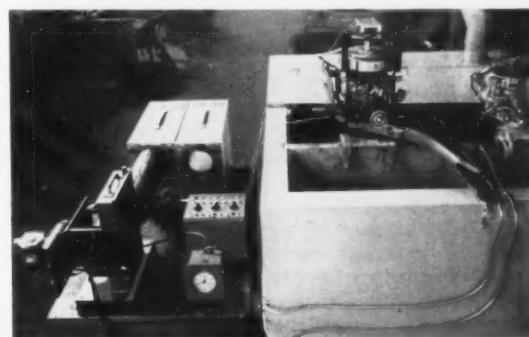
Thus, by testing nine instead of six pairs there are three indirect comparisons of A and E available instead of just one.

There are other useful features connected with these designs. The nine pairs just discussed may be grouped into three sets:

$$\begin{array}{ccc} 1 & 2 & 3 \\ AB & AC & AD \\ EC & ED & EB \\ FD & FB & FC \end{array}$$

Each set of three pairs now involves all six letters. If these are pairs of shoes, one set might be assigned to grade school boys, one set to high school boys, and the remaining set to adults. By taking the *sums* of the six readings associated with any set, a measure of wear as related to age group is available without interfering with the comparison of materials. The same data are thus used for two purposes.

Recent studies of spark plugs at the Bureau made use of one of these arrangements. Six types of spark plugs were involved. They were tested in four two-cylinder outboard motors, each motor having one cylinder above the other. An arrangement of the plugs in cylinders and engines which equalizes possible differences arising



Apparatus used at NBS in recent studies of outboard engine spark plugs. Two of set of four test engines may be seen at right. Spark plug conductance is shown on oscilloscopes at left during the nonsparking part of engine cycle. A strip film camera and stop clock (left foreground) record time oscilloscope traces. A statistical arrangement was worked out which tends to equalize any differences arising from the two cylinder positions or from variations between engines.

from cylinder position or from differences among engines is shown below:

Engine	Run	Cylinder	
		Top	Bottom
I.....	1	A	B
	2	C	E
	3	D	F
II.....	1	B	C
	2	F	E
	3	D	A
III.....	1	A	C
	2	F	B
	3	E	D
IV.....	1	E	A
	2	B	D
	3	C	F

The plan provides that each type of plug be used on every one of the four engines, twice in the top position and twice in the bottom position. The 12 runs accommodate 12 of the possible 15 pairings of the six types.

Any one type (e.g., A) is paired with four others (e.g., B, C, D, E), and through these may be compared with the fifth plug (e.g., F) as follows:

$$\begin{array}{ll} A-B & B-F \\ A-C & C-F \\ A-D & D-F \\ A-E & E-F \end{array}$$

This schedule for the arrangement of plugs in the engines makes it possible to rate all the plugs relative to one another using only the differences in performance between plugs on the same run. The schedule also makes it possible to compare engines because the average for each engine is based on all six plugs. The effect of cylinder position can be evaluated because all six plugs are used twice in each position. Thus the data, besides serving the primary purpose of comparing spark plug performance, are used to reveal additional information about the experimental equipment used in the tests.

For further details, see New experimental designs for paired observations, by W. J. Youden and William S. Connor, *J. Research NBS* 53, 191, (1954); and Partially balanced incomplete block designs with two associated classes and two treatments per block, by Willard H. Clatworthy, *J. Research NBS* 54 (1955) RP2579.

Third Temperature Symposium

AN INTERNATIONAL SYMPOIUM on "Temperature, Its Concept and Measurement" was held at the Bureau in Washington, D. C., on October 28, 29, and 30, 1954, to review the present status of problems in the measurement of temperatures from millidegrees to megadegrees. Included for discussion were such subjects as extremely hot gases, low-temperature scales near absolute zero, highly precise methods for measuring temperature, upper atmosphere temperatures, and the temperatures of shock waves caused by supersonic aircraft.

During the five half-day sessions, a total of 25 technical papers were presented before more than 400 scientists representing industry, government, and university laboratories both in the United States and abroad. The symposium was sponsored jointly by the American Institute of Physics, the National Bureau of Standards, and the Office of Ordnance Research, Department of the Army. Dr. A. V. Astin, Director of the National Bureau of Standards, was chairman of the meeting.

Temperature is one of the most important of the physical quantities. However, its measurement and understanding have provided some of the most difficult and challenging problems, both experimental and theoretical, in the field of physics. Three international symposia have now been held to permit exchange of information between the various groups that work with extreme temperatures and precision temperature measurement, and to stimulate research pertinent to these

fields of interest. The first symposium was held in Chicago in 1919. The second meeting was held in New York City in 1939 and was sponsored by the American Institute of Physics. It covered a wide variety of subjects, and its proceedings were published under the title *Temperature, Its Measurement and Control in Science and Industry* (Reinhold, New York, 1941). The third meeting, in 1954, reviewed and summarized the developments that have taken place since 1939.

The 1954 symposium opened with introductory remarks by Dr. Astin, who reported on the action taken in October 1954 by the Tenth General Conference on Weights and Measures to redefine the absolute temperature scale. The General Conference adopted the proposal made originally by Kelvin in 1854 and reintroduced by Giauque in 1939: to define the absolute scale of temperature on the basis of a single fixed point: this point is to be the triple point of water, to which is assigned the value 273.16° K, exactly.

The opening session of the symposium, with M. W. Zemansky (City College of New York) as chairman, was devoted to discussions of the general concepts of temperature. H. C. Wolfe (Cooper Union) surveyed the general concept of temperature as applied to systems in equilibrium and outlined the procedure for establishing a temperature scale. He also pointed out the limitations to the general concept which arise in attempting to deal with nonequilibrium systems. Some special cases were treated in greater detail by F. E. Simon (Oxford University), who discussed the concept

of temperature near absolute zero, and by G. H. Dieke (Johns Hopkins University), who outlined the procedures and difficulties involved in measuring high temperatures in gases. C. H. Payne-Gaposchkin (Harvard University) presented a survey of the latest measurements of stellar temperatures. In a later session on transient phenomena, a group of papers were presented on the theoretical aspects of the temperature concept under non-equilibrium conditions and on the approach to equilibrium. The speakers for that session were I. Prigogine (Université Libre de Bruxelles), K. F. Herzfeld (Catholic University of America), and J. G. Kirkwood (Yale University).

The experimental aspects of temperature measurements were emphasized in three of the sessions. In a session entitled "Standards and Scales," with F. G. Brickwedde (NBS) as chairman, there were discussions of the current status of the International Temperature Scale and of thermodynamic temperature measurements. J. A. Beattie (Massachusetts Institute of Technology) reviewed the nature of the problems involved in precision gas thermometry. H. Moser (Physikalisch-Technische Bundesanstalt, Braunschweig) described recent measurements made in his laboratory with a new type of gas thermometer on the thermodynamic temperature of the gold point. No determinations of the gold point temperature have been reported since the work of Day and Sosman in 1911. Moser reported that his preliminary determinations give values in essential agreement with the accepted value of 1,063° C. The maintenance of the International Temperature Scale and the methods of precision thermometry at some of the national standardizing laboratories were described by J. A. Hall (National Physical Laboratory, Teddington, England) and H. F. Stimson (NBS). H. Preston-Thomas (Canadian National Research Council, Ottawa) reported on measurements of the stability of the freezing point of zinc, which has been suggested to replace the sulfur boiling point as a fixed point of the International Temperature Scale.

At temperatures below that of the oxygen boiling point (about 90° K) there is no internationally accepted "practical" scale. In this range there is needed a scale that is realizable by thermometers more convenient than the gas thermometer but which is based on primary

calibrations with the gas thermometer. The status of the scales now in use was discussed by R. B. Scott (NBS) for the range 90° to 5° K, and by R. P. Hudson (NBS) for the range 5° to 1° K.

In a session devoted to experimental measurements, with P. E. Klopsteg (National Science Foundation) as chairman, a wide variety of topics were discussed relating to methods for temperature measurement at the extremes of low and high temperature. Included were papers by D. de Klerk (Kamerlingh Onnes Laboratory, Leiden) on methods applicable to the range 0.001° to 1° K, and by H. van Dijk (Leiden) on magnetic methods for temperatures above 1° K. In the high-temperature range H. P. Broida (NBS) presented a survey of methods for temperature measurement in flames and hot gases, with particular emphasis on methods involving the measurement of radiant energy. W. Lochte-Holtgreven (Kiel University) described experiments performed in his laboratory on high-current electric arcs in which temperatures as high as 50,000° K were determined from measurements on the degree of ionization in the arc.

Following the papers on the measurement of extreme temperatures, H. J. Hoge (Leeds and Northrup Co.) described the procedures in use in industrial temperature measurement. The possibilities of using superconductors and semiconductors as thermometers were discussed by J. G. Daunt (Ohio State University), and S. A. Friedberg (Carnegie Institute of Technology). A new thermometer based on the temperature dependence of sound velocity in a gas was described by D. R. Pardee and A. L. Hedrich (Diamond Ordnance Fuze Laboratories).

The final session of the symposium was devoted to the discussion of a number of special topics including measurements of temperature in shock waves, A. R. Kantrowitz (Cornell University); in atomic explosions, F. G. Brickwedde (NBS); and in the upper atmosphere, H. E. Newell, Jr. (Naval Research Laboratory).

Publication of the symposium proceedings is being arranged by the American Institute of Physics. The book is expected to be published by the Reinhold Publishing Corporation by the fall of 1955, under the editorship of H. C. Wolfe of Cooper Union.

Fire Tests of Brick Walls

Fire Tests of Brick Walls, by S. H. Ingberg, presents the results of a comprehensive series of fire tests conducted under controlled conditions to determine the essential properties of brick walls as fire barriers. Besides walls of the usual solid design, a number of hollow walls were included with bricks laid flat or on edge to form one or more unfilled spaces between the brick wythes.

Brick walls of buildings have been generally recognized as effective means of restricting the spread of fire and reducing the loss from conflagrations in built-up areas. Their effectiveness depends upon their

stability under fire conditions and the prevention of ignition of combustible materials near or in contact with the side not exposed to fire.

The information in this report should be useful in attaining economy with the required degree of fire safety in buildings where bricks are used for exterior walls and interior subdividing constructions.

Order National Bureau of Standards Building Materials and Structures Report 143; available for 35 cents from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

A Large Vibration Machine

A VIBRATION MACHINE with a test load capacity of 20,000 pounds has been constructed at the Boulder (Colorado) laboratories of NBS. The machine was built at the request of the Air Force to study behavior of heavy apparatus during air and rail shipment. Assembled under supervision of P. R. Weaver,¹ W. E. Smull,¹ and E. H. Brown of the Bureau staff, the vibration table can produce double amplitudes ranging from 0.020 to 0.065 inch at frequencies up to 60 cycles per second.

Millions of dollars are spent annually to repair or replace apparatus that has been damaged or ruined in normal air or rail shipment. Small, lightweight equipment can usually be packaged in well-padded crates to protect it from damaging shocks and vibrations during transit. However, it is generally much more difficult to protect large, heavy equipment in this fashion. As a result, many larger pieces of apparatus are shipped with no vibration protection at all or with inadequate, built-in shock mounts. The NBS vibration testing facility makes it possible to study the behavior of a wide variety of methods used in packaging, shock mounting, and protecting heavy shipments.

Several types of electrodynamic systems were considered in designing the vibration machine. It was finally concluded that a mechanical vibration-generator would be most practical and reliable, in view of the large force output required by the Air Force and the moderate frequency range. This type of vibration generator chosen uses the inertia reaction of unbalanced counter-rotating shafts to produce simple harmonic motion. The force produced from such a system varies as the square of the driving frequency. The displacement amplitude remains nearly constant.

The machine has two vibration generators, each of which can be given the following unbalance: 50-pound-inches, 180-pound-inches, and 250-pound-inches. The

two mechanisms with the same unbalance can be coupled together and driven as a unit, or the mechanisms may be driven separately as required by the test procedure. These mechanisms, which weigh approximately 500 pounds each, are powered by a 10-hp d-c motor with a variable-speed control.

The vibration generators can be mounted on top of the table for vertical motion, or on the end for horizontal motion. Testing along the third axis is accomplished by rotating the equipment under test 90° in the horizontal plane with the shaker mechanism adjusted for horizontal motion of the table. The table is 12 feet long and 6 feet wide, weighs approximately 11,000 pounds, and is mounted on four coil springs which give the system a natural frequency of 4 cycles per second. Equipment to be tested can be suspended from the underside of the table.

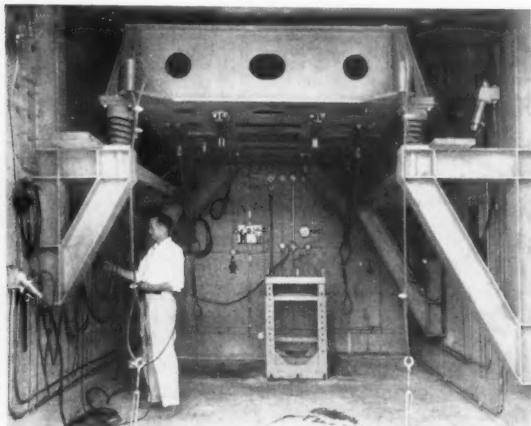
Several tests were performed, prior to using the machine, to determine the characteristics of the over-all system and the type of motion produced by the table. In one test, a 6,800-pound concrete block was suspended from the table, and two 180-pound-inch mechanisms were coupled together and mounted so as to produce horizontal motion. Three accelerometers were attached to the table to measure both the horizontal and vertical components of the motion. Data taken up to 41 cps showed that a maximum horizontal acceleration of 4 g was reached, and that the unwanted component of vertical acceleration did not exceed 0.17 g.

In another test, the concrete block was removed, and the shaker mechanisms were attached so as to produce vertical motion of the table. Accelerometers were oriented along the length of the table so as to measure the variation and magnitude of vertical acceleration produced. The maximum variation in recorded acceleration along the length of the table was 0.35 g. At the highest frequency used in this test—45 cps—the acceleration reading was 6.5 g. (Maximum accelerations of 6 g with a 3,200-pound test object have been recorded.) With two 50-pound-inch mechanisms, the machine has been run to 60 cps. No local resonance of the table or the supporting structures was found within the test frequency range.

This facility is expected to aid materially in the improvement of heavy-duty shock mounting, and in the improvement of apparatus design to eliminate failure due to vibration.

Large vibration machine recently constructed at Boulder (Colo.) laboratories. Equipment has a test load capacity of 20,000 pounds and can produce double amplitudes ranging from 0.020 to 0.065 inch at frequencies up to 60 cps. Four coil springs which support the machine can be seen at the corners of vibration table. Racks used to mount objects to be tested are located on under surface of table. Equipment was built to study behavior of heavy apparatus undergoing vibration associated with normal air and rail shipment. This NBS facility is expected to aid materially in the improvement of heavy duty shock mounting and apparatus design for elimination of failures due to vibration.

¹ Now with the W. L. Maxson Co.



Measurement of Carbon-14 in Solution

A RAPID, precise method for determination of carbon-14 in C¹⁴-labeled substances have been developed by A. Schwebel, H. S. Isbell, and J. D. Moyer of NBS. In this method the labeled material is first dissolved in a suitable solvent and then placed in a modified proportional counter which measures the radioactivity of the material. By keeping the specimen in solution, many of the problems inherent in the use of solid specimens—deposition of films, combustion, or plating of samples—are avoided. The procedure also permits the application of volumetric techniques and is particularly useful for assay of highly active materials.

Use of carbon-14 as a radioactive tracer has become increasingly widespread since its discovery in 1940. Thus, to meet the needs of medical and biological research, the Bureau has prepared over 40 sugars and sugar derivatives having carbon-14 atoms located in specific positions within the molecule. These position-labeled compounds are used as tracers in a variety of complicated animal and plant metabolism studies. With the relatively large-scale availability of carbon-14 as a tool for science and industry, it has become important to develop adequate instrumentation for measuring its beta radiations.

Relatively little instrumentation work has been done on measuring C¹⁴-labeled compounds in solution with windowless proportional counters. Direct measurement of the radioactivity of solid sources is complicated by variations in self-absorption, backscattering, and foreshielding, and (in counting on plastic backings) by the presence of static charges that distort the field. These variations do not occur with solutions, which are quite reproducible and have little tendency to hold static charges. Other complications arise, however, and it is not possible to obtain satisfactory assays with most solvents.

A satisfactory solvent for counting C¹⁴-labeled materials in solution by means of a windowless proportional counter must meet several requirements: (1) it must be an adequate solvent for the material to be analyzed; (2) its vapor pressure must be low to avoid a change in the concentration of the solvent with time; (3) its vapors should not form a conducting path across the high-voltage-wire insulation in the counter; (4) it must have little or no tendency to creep over the edge of a container.

Numerous liquids were investigated at the Bureau in an effort to find a suitable solvent. Of those studied,

90-percent phosphoric acid was found fairly satisfactory while purified formamide, dimethyl formamide, and ethylene glycol gave excellent results.

The solution to be assayed can be prepared by any convenient method. Readily soluble materials are dissolved directly in the counting liquid. Samples received in aqueous solution are handled by first taking a definite volume (up to 0.1 ml) of the sample in a mixing pipet and then adjusting the volume to 1 ml with the solvent. The separation of insoluble precipitates or of a second liquid phase must of course be avoided. To minimize errors that might arise from adsorption of the radioactive material on the container or from concentration of the sample on the surface of the counting liquid, highly active materials are diluted with a suitable quantity of the corresponding nonradioactive material when the solution is prepared for counting.

To adapt commercially available proportional counters for the assay of liquid samples, it is necessary to fit them with a suitable container for the liquid. A stainless-steel cell holding a maximum of 1.1 ml of solution was used in this study. To prevent contamination of the counter, the cell is handled by means of a bolt that fits a tapped hole and serves as a removable handle. The container is water-cooled to prevent decomposition of the formamide and to minimize evaporation of volatile constituents from the solution.

The proportional counter used is designed so that a continuous stream of gas flows at atmospheric pressure through the counting chamber which contains the material to be analyzed. After the solution is placed in the counter, the system is thoroughly flushed with the counting gas and the run is made. Radiation from the material under analysis produces ionization in the chamber; this leads to a momentary discharge across the high-voltage field maintained between the wall of

A C¹⁴-labeled material in solution is added to the water-cooled cell of a commercial proportional counter that has been adapted for use in a liquid counting technique developed at NBS. The amount of radioactive carbon-14 in the material under test is determined by dissolving the sample in a suitable solvent and comparing radioactivity of this solution to that of a solution of known beta-ray intensity.



the chamber and a wire anode. The change in potential caused by the discharge is converted into a current pulse that activates a recording mechanism by means of a vacuum-tube amplifier. For maximum precision, background determinations are made before and after each measurement.

To convert the observed counts per second (cps) to the absolute disintegration rate (dps) or to microcuries of C¹⁴ per milliliter of solution, it is necessary to standardize the procedure by counting a solution containing a C¹⁴-labeled substance of known radioactivity under conditions comparable to those used in the analysis. In the present study several such substances were used for standardization.

To prepare a solution of a material for use in standardizing the counter, the radioactivity of the material is determined by oxidizing it, transferring the carbon dioxide to an ionization chamber, and using this chamber with a vibrating-reed electrometer. The electrometer rate of drift obtained with this unknown is then compared to the drift rate obtained with the carbon dioxide in a sample of the NBS C¹⁴ Beta Ray Standard. A known concentration of the standardized material in formamide or other solvent is then used to determine the efficiency of the counter.

Any comparison of counting rates must take into consideration the density of the solution used because the absorption of beta radiation is proportional to the density of the absorbing medium. For this reason, the counting efficiency (cps/dps) in a given counter should be inversely proportional to the density of the solution counted.

A detailed study of data for D-mannitol-1-C¹⁴ dissolved in a variety of solvents and for a number of C¹⁴-

labeled materials dissolved in the same solvent shows that the product of the counting efficiency and the density is substantially a constant regardless of the substance counted or the solvent. This gives rise to a constant calibration factor that can be used for converting the count of an unknown sample to microcuries of C¹⁴ per milliliter. Thus for all carbon-14 labeled materials the absolute disintegration rate in microcuries is given by the product of the observed counting rate, the density of the solution, and the calibration factor.

Densities of solutions containing small quantities of a solute in a particular solvent do not vary widely. Hence, it is not necessary to determine densities of all solutions for routine measurements. Frequently no substantial error is introduced by using the density of the solvent as the density of the solution.

To obtain an indication of the precision of the solution counting technique, measurements were made at the Bureau on a C¹⁴-labeled sugar in formamide and in ethylene glycol using three proportional counters differing slightly in counting efficiency. A statistical treatment of the disintegration rate of a radioactive substance would lead one to expect a standard deviation in these measurements of ± 309 for 95,000 counts. The actual standard deviations obtained for the experimental data are only slightly higher than this value, indicating that C¹⁴-labeled compounds can be reproducibly counted in solutions of either formamide or ethylene glycol.

For further technical details, see Determination of carbon-14 in solutions of C¹⁴-labeled materials by means of a proportional counter, by A. Schwebel, H. S. Isbell, and J. D. Moyer, *J. Research NBS* **53**, 221 (1954) RP2537.

Effect of Soils on Asbestos-Cement Pipe

DETAILED INFORMATION regarding the effect of soil exposure on the properties of asbestos-cement pipe has resulted from field studies recently completed by M. Romanoff and I. A. Denison of the Bureau. Representative specimens were exposed to a wide variety of soil types for periods up to 13 years and, upon removal, the physical and mechanical properties of the pipe specimens were carefully investigated. The data thus obtained provide an over-all picture of the rate and extent of alteration of this type of pipe in the soils studied.

Asbestos-cement pipe is widely used in underground water pipelines. It is also used to considerable extent in sewage disposal, in oil fields to remove salt water, and in various industrial applications. However, little specific information has been available regarding its behavior in soils. The Bureau's investigation of this material was part of a long-range program to determine

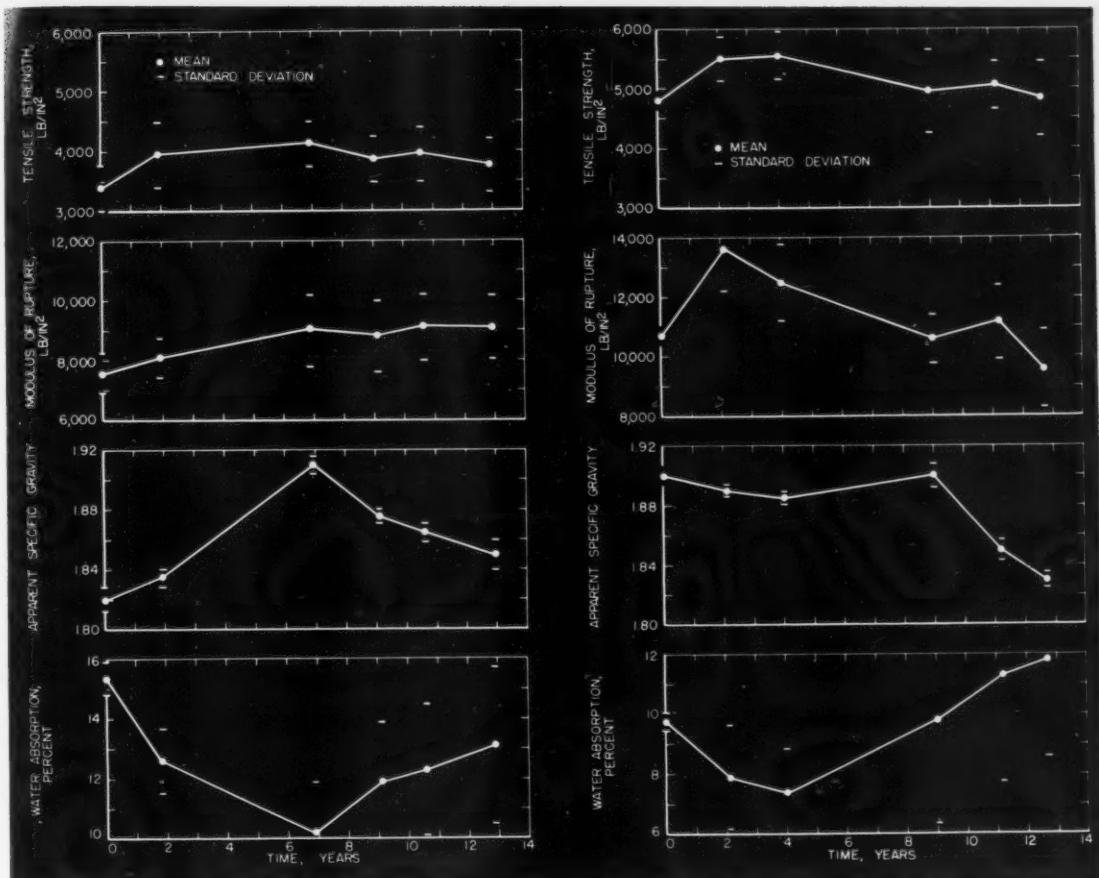
the effects of various soils on materials for underground construction.

Asbestos-cement pipe is a mixture of approximately 80 percent by weight of portland cement and 20 percent asbestos fibers. It is built up continuously on a revolving steel mandrel and compacted under heavy pressure, then subjected to a curing operation. Practically all the asbestos-cement pipe used in the United States is produced in this way.

Exposure studies included two varieties of asbestos-cement pipe specimens, one 4 inches, the other 6 inches in diameter, designed to withstand a pressure of 150 lb/in.² (class 150 pipe). Both sizes of pipe were fabricated in essentially the same manner from a thin slurry of portland cement and asbestos fibers, but there were minor differences in the technique used to transfer the slurry to the mandrel upon which the pipe was formed. After removal from the mandrel, the 6-inch pipe was cured by a high-pressure steam process while the 4-inch pipe was cured by submersion in water for 2 to 3 weeks.

Six-inch specimens were removed from the 15 expo-

For further technical details, see The effect of exposure to soils on the properties of asbestos-cement pipe, by M. Romanoff and I. A. Denison, *Corrosion* **10**, 169 (1954).



Results of soil-exposure studies of asbestos-cement pipe. Average tensile strength, modulus of rupture, apparent specific gravity, and water absorption in 14 soils are plotted for different periods of exposure. *Left:* Graphs of 4-inch pipe. The data for tensile strength and modulus of rupture are adjusted to the saturated condition. *Right:* Graphs of 6-inch pipe. Measurements of tensile strength and modulus of rupture were made on specimens in the saturated condition.

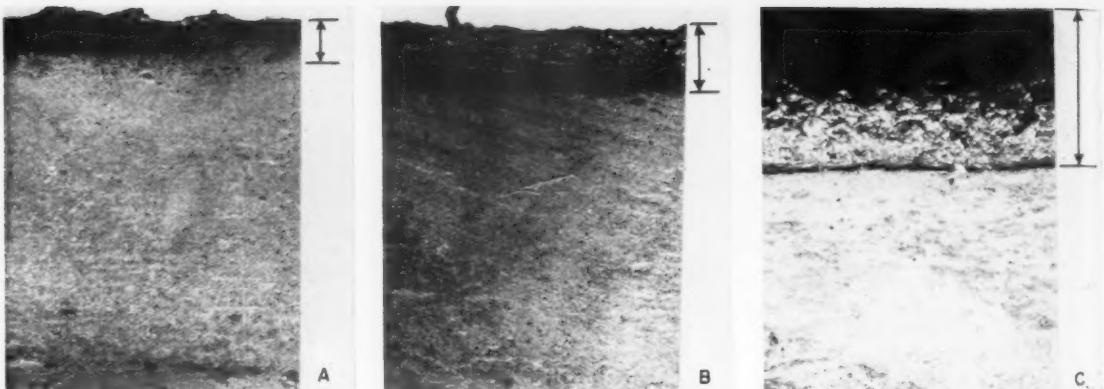
sure sites after periods of 2, 4, 9, 11, and 13 years. Four-inch specimens were taken up at the end of 2, 7, 9, 11, and 13 years. After removal, specimens were returned to the laboratory for determination of the effects of exposure to the soils as indicated by measurements of hydrostatic bursting strength, crushing strength, water absorption, apparent specific gravity, and condition of the surface of the specimens. Representative specimens of unexposed pipe of both types were also subjected to the same tests, to supply reference data in determining the effects of the various soils and periods of exposure on the pipe materials.

Saturation with water reduces the strength of asbestos-cement pipe from 10 to 20 percent. Thus, in order to simulate service conditions with respect to moisture, the 6-inch specimens were immersed in water for 48 hours before subjecting them to bursting and crushing tests. The 4-inch specimens were tested in the air-dry condition and then adjusted to the water-saturated con-

dition by reducing the values for tensile strength and modulus of rupture by 15 percent.

Surface condition of the specimens was determined semiquantitatively by scratching the external surface and, more objectively, by grinding under carefully controlled conditions until the measured hardness was equal to that of the unexposed reference pipe. The thickness of the removed layer was then taken as a measure of the softening of the surface.

In general, the data show an increase in strength during the early periods of exposure followed by a decrease in strength during the latter periods. The increased strength, which is generally accompanied by a decrease in water absorption, is associated with a curing process that continues for several years during exposure to the soil. After the completion of the curing process, the specimens were subject to weathering, as manifested by loss in strength, decrease in apparent specific gravity, increased absorption of water, and superficial softening.



Cross sections of asbestos-cement pipe exposed in different soils for 13 years. Depth of softening due to weathering is indicated by the thickness of the dark layers opposite arrows. Specimen A was exposed to Lake Charles clay, specimen B to muck, and C to Rifle peat.

Averages of the strength and water-absorption measurements indicated that the curing period was 2 to 4 years in the 6-inch pipe, as compared with approximately 7 years in the 4-inch pipe. This longer curing period may be due not only to different initial curing processes but to differences in dimensions, composition, and method of fabrication. Weathering also proceeded more rapidly in the larger than in the smaller pipe.

Rate and extent of alteration of the specimens were affected considerably by the nature of the soil conditions to which they were exposed. For example, weathering was accelerated by both organic and inorganic acidity. Cement products are altered by the process of hydrolysis, and the rate of hydrolysis is increased by hydrogen ions, which are present in soils as carbonic acids. Since the decomposition of organic matter provides a large amount of carbonic acid to the ground water and so increases its activity, relatively greater losses in strength of portland cement would be expected in soils high in organic matter.

Average tensile strength of the 6-inch pipe after 13 years' exposure was of the same order of magnitude as that of the unexposed pipe, and that of the 4-inch pipe was still higher. Even under the most adverse conditions to which the specimens were exposed, the bursting and crushing strengths of all the samples after exposure were higher than the requirements of the Federal Specifications for asbestos-cement pipe.

Note:

Other references on corrosion studies conducted by the National Bureau of Standards. Underground corrosion, by K. H. Logan, NBS Circular 450 (1945); Soil-corrosion studies, 1946; Ferrous metals and alloys, by I. A. Denison and M. Romanoff, J. Research NBS 44, 47 (1950) RP2057; Soil-corrosion studies, 1948; Copper and copper alloys, lead and zinc, by I. A. Denison and M. Romanoff, J. Research NBS 44, 259 (1950) RP2077; Corrosion of galvanized steel in soils, by I. A. Denison and M. Romanoff, J. Research NBS 49, 299 (1952) RP2366, also Corrosion 9, 132 (1954); Corrosion of low-alloy irons and steels in soils, by I. A. Denison and M. Romanoff, J. Research NBS 49, 315 (1952) RP2367, also Corrosion 9, 141 (1953).

Automatic Photoelectric Ozone Detector

AN AUTOMATIC photoelectric instrument for continuous measurement of the ozone in the earth's atmosphere at low altitudes has been developed at the Bureau under the sponsorship of the Army Ordnance Department. Devised by R. Stair, T. C. Bagg, and R. G. Johnston of the Bureau's radiometry laboratory, the system makes use of the optical absorption characteristics of ozone in certain ultraviolet spectral bands. It is expected that the NBS development, which can determine ozone concentrations of a few parts per billion, will provide valuable information on air-mass movement and other weather phenomena. It is now being set up for use in a study of the Los Angeles smog problem. Other possible applications include the correlation of the visible deterioration effects of ozone on rubber with accurate measurements of ozone concentration in the atmosphere.

Ozone is normally produced in significant amounts only at high altitudes in the stratosphere. Here short-wave ultraviolet radiation from the sun causes photochemical dissociation of the oxygen molecule, and the oxygen atoms recombine to form ozone. Because ozone is an active oxidizing agent, the presence of organic particles in the atmosphere, together with the effects of long-wave solar radiation and increased temperature at lower altitudes, results in the destruction of most of the ozone molecules below heights of 9 to 11 miles under normal conditions of atmospheric circulation. Thus, any appreciable quantity of the gas found at the surface of the earth must have been transported there by some means. Diffusion is slow and hence for the lower altitudes may be disregarded. Therefore, any ozone transportation at a rate sufficient to upset the static balance at the surface of the earth must be due to gen-

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eral large-scale airmass movements associated with cyclonic and anticyclonic conditions, together with local air circulation resulting from thunderstorms and the like. This fact makes ozone concentration measurements of value in studying weather phenomena.

Ozone is an important constituent of the atmosphere because of its protective effect in absorbing shortwave solar radiation, but it is also highly deleterious to rubber and related organic products. Interest in the deteriorating effect of ozone on rubber materials has increased greatly in recent years with the development of new synthetic elastomers having varying degrees of ozone resistance. Although ozone is only one of several agents influencing the deterioration of rubber materials under the complex conditions of exposure to weather, it frequently proves to be the most severe. Simple methods for accurate measurement of its concentration have been urgently needed.

While various chemical methods for the measurement of ozone have been suggested or devised, most of these require close attention, and give results which are an average over an interval of time. The apparatus developed by the Bureau makes possible a physical method based on the strong absorption characteristic of ozone in the spectral region centered between 2500 and 2600 Å (Hartley band). Using this spectral absorption, changes in the amount of ozone in the air are determined as a function of variations in the energy received at a detector from an ultraviolet source.

In the present setup, a steady source of ultraviolet energy is placed approximately 1,500 feet away from, and directed at, a sensitive photoelectric detector. A bank of five commercial low-pressure mercury arc lamps is used as the energy source. The source is equipped with a glass tube that absorbs the 1847 Å emission line of the lamps but transmits the 2537 Å line and others of longer wavelength. In order to eliminate as far as possible the effect of other sources of light that might fall upon the photodetector, the radiant energy from

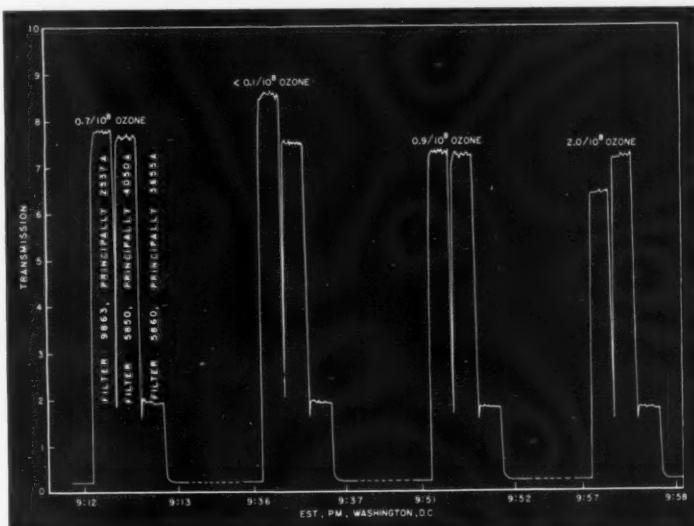
the source is modulated at 510 cps. This is done by means of a synchronous rotating sector disk driven at 1,300 rpm.

At the detector station the modulated light beam is picked up by a 1P28 photomultiplier connected with a tuned amplifier and recorder. A special photometer unit contains a mechanism for automatically changing optical filters over the photomultiplier. A set of three glass filters is arranged on a disk, so that alternate readings are made at three regions within the spectrum. The first of these is at 2537 Å, the second at 3655 Å, and the third in the blue region. Each filter is placed in front of the photomultiplier for 15 seconds, after which the filter disk is rapidly moved to a new position for the next filter in the series. The fourth filter position carries an opaque shutter. Hence, during each minute a complete series of measurements is recorded. In order to correct for any scattered radiation from surrounding city lights, the moon, or other sources that might reach the photodetector, a shutter is automatically interposed in the light beam for about 1 minute every 15 minutes.

By means of a timing clock, the source may be automatically turned on before a similar clock starts the receiving apparatus. Likewise, the clocks turn off the equipment at a prearranged time each night. As all the components are controlled by timing clocks, the equipment requires no personal attention during periods of operation. Only daytime servicing and noting of weather data are required.

As the radiant energy from the five source lamps is extremely low after being transmitted approximately 1,500 feet, the modulated source and the tuned-circuit amplifier are required in order to eliminate the zero drift resulting from the variable dark current in the photomultiplier. The photomultiplier is commonly operated at about 70 volts per anode, which results in a voltage amplification of the detected signal of about 100,000. Following this, a tuned a-c amplifier (with a voltage gain of several thousand) is employed to im-

Sections of a recorder tracing made with the NBS automatic photoelectric ozone detector. The record shows the fluctuations in ozone concentration at Washington, D. C., on April 3, 1953.



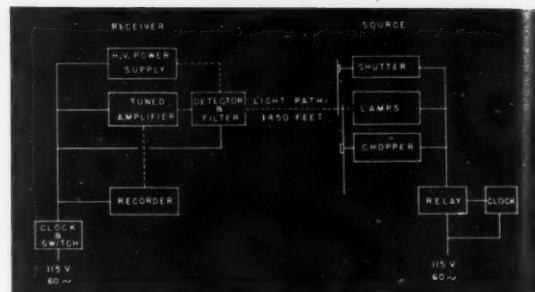
prove the signal-to-noise ratio and to obtain sufficient voltage for operating a standard strip recorder.

Because of the sensitivity of the photomultiplier to voltage changes, a carefully regulated power supply is essential for precision work. The power supply used contains many of the circuit elements commonly employed in conventional units to keep the output voltage constant over a wide range of input voltage. As the electric load of the amplifier is relatively constant, little attention need be given to regulatory devices to cover load variations.

Because the outputs of low-pressure mercury-arc lamps are affected by their operating temperatures, large changes in temperature of the lamps used in the present apparatus are eliminated by enclosing the five lamps in a box. The radiation from the lamps emerges through a small quartz-glass window installed in one side of the box.

Selective scattering of radiation by the atmosphere has been neglected in the Bureau's ozone measurements. However, the effect of this scattering is small, and any error resulting from it is much less than that caused by other erratic changes in the atmosphere. Furthermore it is assumed that any scattering by dust particles is non-selective and therefore does not affect the transmission ratios on which the evaluation of ozone is based.

Absorption by various impurities in the atmosphere, such as smoke or other combustion or chemical vapors associated with industry or housing, produces errors of unknown magnitude. Hence, the method cannot safely be employed where any vapors having absorption in the ultraviolet spectrum (at the wave lengths of the mercury emission lines) may be intermittently present. Many chemical and combustion vapors are known to have



Block diagram of the automatic photoelectric ozone detector. The device makes use of the strong optical absorption characteristics of ozone in certain ultraviolet spectral bands. A time-controlled mechanism changes three glass filters between the lamps and the detector so that radiant energy from the lamps is separated into bands primarily at wavelengths 253.7, 365.5, and 405.0 millimicrons. From the ratios of the deflections for the different spectral regions, it is possible to determine ozone concentration down to several parts per billion.

high ultraviolet absorption. Chimney vapors from the burning of coal, for example, when blown into the light beam cause erratic recorder tracings.

For daylight operations, the NBS instrument must be properly shielded from scattered sunlight. Radiations in the spectral region of 3200 to 4000 Å, which are present in sunlight, will overload the 1P28 photomultiplier and will make its modulated response nonlinear. When better filters become available, it should be possible to confine the response to those wavelengths that are not present in sunlight. Daytime operation would then be as convenient as nighttime use.

Solution of Linear Equations

EDITED by Olga Taussky, *Contributions to the Solution of Systems of Linear Equations and the Determination of Eigenvalues*, describes many methods of solving linear equations and inverting matrices. Most emphasis is on elimination methods and on related schemes involving the triangular resolution of matrices, but some attention is given to iterative solutions. Twenty-six numerical examples (usually for matrices of order six) are given, with complete computational layout and full details. The seven papers presented will be helpful to mathematicians and physicists and

to engineers working in all fields of physical science where problems may be expressed in the form of simultaneous equations. Since this is one of the most common forms in which both theoretical physical problems and physical data may be expressed, the scope of the fields in which this material has possible application is wide. The volume should be of particular value to agencies and organizations having high-speed digital computing machines. Order National Bureau of Standards Applied Mathematics Series 39, 139 pages, \$2.00, from the Government Printing Office, Washington 25, D. C.

Electrometric pH Determinations

THE FUNDAMENTAL PRINCIPLES and conventions of pH, its theory, measurement, and a practical handbook of information are contained in a new 331-page book, *Electrometric pH Determinations, Theory and Practice* (John Wiley & Sons, \$7.50), by Roger G. Bates of the NBS physical chemistry laboratory. This new book ties a modern discussion of pH

to modern commercial pH equipment. It explains the fundamental reasons why the pH value is not an exact physical quantity, and shows clearly how far theory can go in pH measurement. The book also presents a full discussion of the standard pH scale (conventional activity scale) and the NBS pH standards, which are gradually being adopted throughout the world.

The early chapters are primarily concerned with the theoretical aspects of pH, and include an examination of several assumptions upon which the estimation of liquid-junction potentials and individual ionic activities can be based. The application of these assumptions in the establishment of pH standards is given detailed consideration. The treatment also indicates how far the exact thermodynamic approach can be pursued before empirical standardization begins. Properties of buffer solutions and the selection of mixtures for pH control are discussed. As far as possible, dissociation equilibria and salt effects are treated rigorously. The book

also gives detailed instructions for the preparation of standard solutions and shows the difficulties involved in establishing useful scales for acidity and basicity in nonaqueous media.

Four chapters discuss the many experimental aspects of pH determinations. The selection, preparation, and errors of electrodes and salt bridges are considered; the design, operation, and care of pH meters and related instruments is described; and the equipment and methods of automatic control systems are discussed. Because of the importance of glass electrodes, a separate chapter is devoted to their properties.

Two New Motion Picture Films

A True Standard

This new NBS 16 mm, sound and color 12 minute film shows the importance of accurate standard weights and precise weighing techniques and illustrates certain activities of the Federal, State, and local governments in weights and measures administration. The step-by-step relationship between the international standard of mass and the test weights used by an inspector in testing store scales is told. Film action takes place in France; the National Bureau of Standards in Washington, D. C.; a State Office of Weights and Measures; and in a modern supermarket. The film also serves as a useful and interesting introduction to the theory of substitution weighing. This method is used widely and is recommended for very accurate weight determinations in science, industry, and commerce. A second version of the film containing a 7 minute instruction section on the method of substitution weighing is also available to specialized audiences.

Dental Burs In Action

This 16 mm, sound and color 10 minute film produced by NBS in cooperation with the U. S. Air Force Dental Service, is intended to aid the dentist in a better understanding of the operating principles of rotating dental cutting instruments. Through the medium of high-speed motion picture photography and easily understood bar graphs, the ability of different types of dental burs to cut hard and soft tooth structures is explained in this new film. The achievement of rapid cavity preparation with a minimum of discomfort to the patient is outlined and the need for selection of the proper cutting instrument, dependent upon the type of tooth structure being cut, is stressed. The film is designed for showing to professional groups, at clinics or scientific sessions where general practitioners of dentistry may be assembled. It is also of value as a teaching aid in dental schools for graphically demonstrating the principles of rotating instrument selection and use.

For information about the loan or sale of these films, write to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

Publications of the National Bureau of Standards

Journal of Research of the National Bureau of Standards, volume 54, number 1, January 1955 (RP2559 to R2565 incl.). Annual subscription \$4.00.
Technical News Bulletin, volume 39, number 1, January 1955. 10 cents. Annual subscription \$1.00.
CRPL-125. Basic Radio Propagation Predictions for April 1955. Three months in advance. Issued January 1955. 10 cents. Annual subscription \$1.00.

Research Papers

Reprints from *Journal of Research*, volume 54, number 1, January 1955. Single copies of the *Journal* vary in price. Single copies of *Research Papers* appearing in the *Journal* are not available for sale. The Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., will reprint 100 or more copies of a *Research Paper*. Request for the purchase price should be mailed promptly to that office.

- RP2559. Calibration of meter line standards of length at the National Bureau of Standards. Benjamin L. Page.
- RP2560. Enthalpy and specific heat of four corrosion-resistant alloys at high temperatures. Thomas B. Douglas and James L. Dever.
- RP2561. Effect of temperature on the tensile properties of a commercial and a high-purity 70-percent-nickel-30-percent-copper alloy. William D. Jenkins, Thomas G. Digges, and Carl R. Johnson.
- RP2562. The system lime-water at 21° C and high pressures. Charles E. Weir.
- RP2563. Absorption of radiant energy by solid particles in suspension. James E. Stewart.
- RP2564. Branching ratio in the decay of polonium-210. R. W. Hayward, D. D. Hoppes, and W. B. Mann.
- RP2565. Mechanism of high-speed-waterdrop erosion of methyl methacrylate plastic. Olive G. Engel.

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U. S. DEPARTMENT OF COMMERCE
SINCLAIR WEEKS, Secretary
NATIONAL BUREAU OF STANDARDS
A. V. ASTIN, Director

February 1955 Issued Monthly Vol. 39, No. 2

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NBS Publications (*continued*)

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AMS37. Tables of functions and of zeros of functions. \$2.25.
AMS44. Tables of salvo kill possibilities for square targets. 30 cents.

Building Materials and Structures Reports

BMS143. Fire tests of brick walls. S. H. Ingberg. 35 cents.

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M213. Biennial report 1953 and 1954 of the National Bureau of Standards. 60 cents.

Publications in Other Journals

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Patents

(The following U. S. Patent has been granted to NBS inventors.)

No. 2,693,706. November 9, 1954. Method of and graded spheres for calibrating sieves. Victor R. Carpenter (Research Assoc.) and Victor R. Deitz. Assigned to the United States of America as represented by the Secretary of Commerce.

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